5.3. **Near-Far Ratio for indoor Part 15 blocking LMS fixed site**

Another method of assessing interference is to calculate the relative distances of the wanted and unwanted transmitters from the receiving station for the threshold of blocking. This is shown diagrammatically in Figure 1.

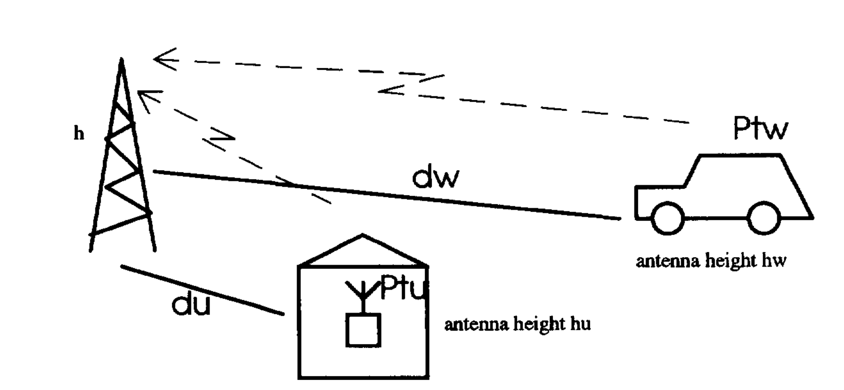

Figure 1 - Part 15 interfering with WB fixed site reception

Using 'Egli', the wanted received signal level is :

$$Prw = Ptw - 114.7 - 20 \log F + 20 \log hw.h - 40 \log dw$$

The unwanted received signal level is :

$$Pru = (Ptu - f) - 114.7 - 20 \log F + 20 \log hu.h - 40 \log du$$

5.3.1. Location burst.

The unwanted signal will be effectively reduced by the Jamming Margin (JM) of the wideband spread spectrum receiver, hence, for threshold of blocking:

$$Pru = Prw + JM$$

or

$$(Ptu - f) + 20 \log hu.h - 40 \log du = Ptw + 20 \log hw.h - 40 \log dw + JM$$

$$40 \log dw/du = (Ptw + JM) - (Ptu - f) + 20 \log hw/hu$$

Table 3 gives the calculated results for the threshold of blocking of the location transmission by an indoor Part 15 radio.

Table 3 - Calculation of Near-Far ratio Indoor Part 15 blocking LMS fixed site location burst					
Ptw, dBm	**40**	40	40	**40**	40
JM, dB	**15**	15	15	**15**	15
Ptu, dBm	**30**	20	10	**0**	-10
hw, ft	**6**	6	6	**6**	6
hu, ft	**6**	6	6	**6**	6
f, dB	**10**	10	10	**10**	10
dw/du	**7.50**	13.34	23.71	**42.17**	74.99
dw =	**6**	miles			
du =	**0.80**	0.45	0.25	**0.14**	0.08

Table 3 confirms the desensitization shown in 5.3.1. An indoor Part 15.247 device within 0.8 miles of the LMS fixed site, reduces the range of a mobile from the LMS fixed site to 6 miles.

Summary

Near-Far-Ratio Indoor Part 15 and LMS Fixed site, for reception of location signals
Indoor Part 15.247 NFR = 7.5
Indoor Part 15.249 NFR = 42.17

The actual interference experienced will be a statistical problem concerning the possibilities of:

a) a mobile being further than a certain distance from the fixed site,

b) a Part 15 radio being within a certain distance of a fixed site,

c) a mobile transmitting,

and d) a Part 15 device transmitting.

Certain indoor Part 15 radios, such as cordless phones, are used infrequently. Other devices, such as wireless PBXs, are transmitting much more often.

These results show that the indoor Part 15.247 devices could cause significant desensitization of LMS fixed sites and reduce the effective range of mobiles to about 6 miles[4]. This represents a significant economic consequence as more fixed sites will need to be installed.

5.3.2. Data and Voice channels

In the MobileVision system, narrow band, 12.5 kHz, channels are also transmitted to and from the mobile. Not all fixed sites transmit these signals, in fact, only about 1 in 3[5].

The maximum transmitted power for a Part 15.247 device is 8 dBm in a 3kHz band, which corresponds approximately to a 500kHz spread bandwidth. 1,2 and 4 MHz bandwidths correspond to 5, 2 and -1 dBm respectively. Therefore in a 12.5 kHz band, the maximum transmitted power (Ptu) is:

Spread	12.5 kHz B/W
500kHz	14 dBm
1 MHz	11 dBm
2 MHz	8 dBm
4 MHz	5 dBm.

For the threshold of blocking:

$$Pru = Prw - S/N \qquad \text{ignoring fade margins.}$$

(S/N is the required output signal to noise ratio)

or $$40 \log dw/du = (Ptw - S/N) - (Ptu - f) + 20 \log hw/hu$$

Table 4 shows the calculated results.

[4]The theoretical range of a mobile transmitting 10W and a receiver with PG = 24 dB, NF = 6 dB, S/No = 10 dB and antenna height 200 feet is 19 miles.

[5]A typical LMS system consists of recieve only sites, for the reception of the location bursts, and transmit/receive sites which also transmit the command and data/voice channels.

Table 4 - Calculation of Near-Far ratio				
Indoor Part 15 blocking LMS fixed site reception of narrow band channels				
Ptw, dBm	40	40	40	40
S/N, dB	10	10	10	10
Ptu, dBm	14	11	8	5
hw, ft	6	6	6	6
hu, ft	6	6	6	6
f, dB	10	10	10	10
dw/du	4.47	5.31	6.31	7.50
dw =	6	miles		
du =	1.34	1.13	0.95	0.80

Comparing Tables 3 and 4 shows that the interference to the narrow band channels is similar to the interference to the location pulse.

5.4. Near-Far Ratio for indoor Part 15 blocking LMS mobile

The LMS mobile receives high power (300W ERP) narrow band data signals on its command channel and, in the MobileVision system, lower power (10W) data and voice signals. Obviously the lower power signals are the most at risk.

Figure 2 shows diagrammatically the situation. Table 5 gives the calculated results.

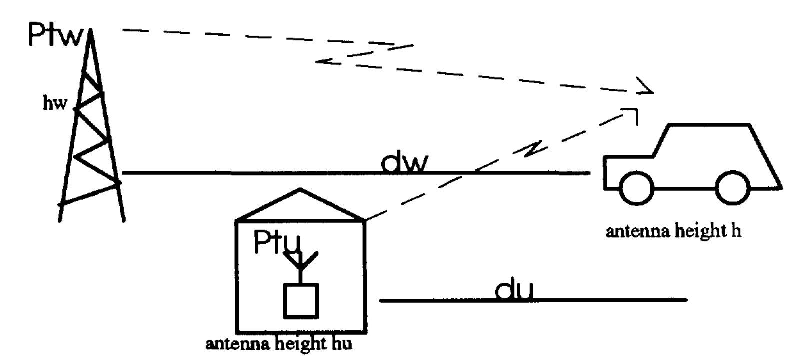

Figure 2 - Indoor Part 15 interfering with WB mobile reception

Table 5 - Calculation of Near-Far ratio

Indoor Part 15 blocking LMS mobile

reception of narrow band channels

Ptw, dBm	40	40	40	40	40
S/N, dB	10	10	10	10	10
Ptu, dBm	30	14	11	8	5
hw, ft	200	200	200	200	200
hu, ft	6	6	6	6	6
f, dB	10	10	10	10	10
dw/du	25.79	30.65	36.43	43.30	57.74
dw =	6	miles			
du =	0.23	0.20	0.16	0.14	0.10

Table 4 shows that this interference is negligible, even for 1W emissions from the indoor Part 15 device.

5.5. Near-Far Ratio for LMS mobile blocking indoor Part 15

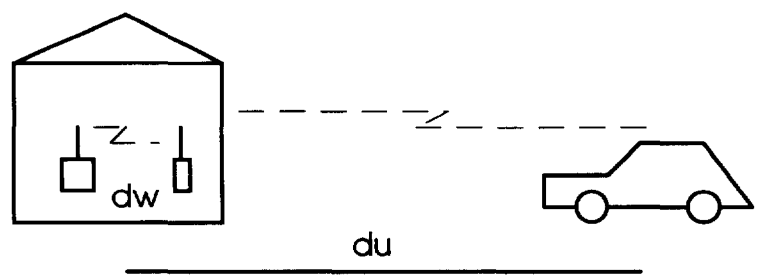

Figure 3 - LMS mobile blocking indoor Part 15 reception

Figure 3 shows diagrammatically an LMS mobile signal interfering with an indoor Part 15 receiver. The same formula as given in 5.3.1. applies except that in this case it is the mobile signal that is attenuated by the 'floor attenuation factor', f. The jamming margin of the Part15 device is assumed to be zero[6]. Table 6 gives the calculated results.

Table 6 - Calculation of Near-Far ratio

LMS mobile blocking Part 15 indoor device

Ptw, dBm	**30**	20	10	**0**	-10
JM dB	**0**	0	0	**0**	0
Ptu, dBm	**40**	40	40	**40**	40
hw, ft	**6**	6	6	**6**	6
hu, ft	**6**	6	6	**6**	6
f, dB	**10**	10	10	**10**	10
dw/du	**1.00**	0.56	0.32	**0.18**	0.10
dw =	**50**	feet			
du =	**50.00**	88.91	158.11	**281.17**	500.00

[6] The specification 15.247 only requires a processing gain of 10dB. For an output signal to noise ratio of 10dB, this is equivalent to a jamming margin of zero.

Table 6 shows that the interference of an indoor Part 15 radio (15.247 or 15.249), with the narrow band, or spread spectrum transmissions of an LMS mobile, are negligible as long as the operational distance of the Part 15 device is short.

The actual interference will be a statistical problem concerning the possibility that a mobile is close enough and is transmitting at the same time that the Part 15 device is operating. Many indoor Part 15 devices, such as cordless phones, are not constantly operating.

If the Part 15.247 radios were designed with jamming margins better than OdB, then the interference potential could be significantly reduced.

Indoor Part15.249 devices are narrow band and, because they have a large number of channels, can easily avoid the LMS frequencies[7].

[7]This is discussed for the outdoor Part 15 situation in Section 8.4.

5.6. Near-Far Ratio for LMS fixed site blocking indoor Part 15

Tables 7 and 8 give the calculated results for the high power command channel and the low power data/voice channels, respectively.

Table 7 - Calculation of Near-Far ratio

LMS fixed site blocking Part 15 indoor device

command channel

Ptw, dBm	**30**	20	10	**0**	-10
JM dB	**0**	0	0	**0**	0
Ptu, dBm	**55**	55	55	**55**	55
hw, ft	**6**	6	6	**6**	6
hu, ft	**200**	200	200	**200**	200
f, dB	**10**	10	10	**10**	10
dw/du	**0.07**	0.04	0.02	**0.01**	0.01
dw =	**50**	feet			
du =	**684.56**	1217.33	2164.76	**3849.54**	6845.57

Table 8 - Calculation of Near-Far ratio

LMS fixed site blocking Part 15 indoor device

data/voice channels

Ptw, dBm	**30**	20	10	**0**	-10
JM dB	**0**	0	0	**0**	0
Ptu, dBm	**40**	40	40	**40**	40
hw, ft	**6**	6	6	**6**	6
hu, ft	**200**	200	200	**200**	200
f, dB	**10**	10	10	**10**	10
dw/du	**0.17**	0.10	0.05	**0.03**	0.02
dw =	**50**	feet			
du =	**288.68**	513.35	912.87	**1623.34**	2886.75

From Tables 7 and 8, as long as the operational distance of the Part 15 device is not too great, the Part 15 device is unlikely to experience interference.

It is possible that Part 15 devices very near, say within half a mile of an LMS transmitting site, may experience some interference.

Narrow band Part 15.249 radios would have to be exactly on the command channel frequency to experience interference.

5.7. Summary

There is a possibility that indoor Part 15.247 devices, operating within a mile of a wideband LMS fixed site, will desensitize that site by 20dB, effectively reducing its range by a factor of 3.

Indoor Part 15.249 devices would need to be within a third of a mile in order to cause the same effect.

There is negligible interference from an indoor Part 15 radio to the LMS mobiles.

There is a low probability of interference to the indoor Part 15 radio from wideband LMS mobiles.

Indoor Part 15 devices could experience interference from the LMS forward links and narrow band data/voice signals if a transmitting LMS fixed site is within half a mile.

If the operating distance of the indoor Part 15 device is kept short, then the chance of interference is very low, as the operating distance increases, then the chance increases. The near-far-ratio (NFR) figures can be used to quantify this.

The use of correct power levels, related to the distance of the Part 15 link, and the sensible use of diraectional antennas would alleviate most of the problems. In the isolated cases where interference still occured, the Part 15 device could be easily moved to the center of the band.

6. *Outdoor Part 15 radio interference.*

The identical analysis used above for the indoor Part 15 devices applies to the outdoor devices, with the exception that the 'floor attenuation factor' is omitted and the height of the outdoor Part 15 device is taken as 30 feet.

6.1. Outoor Part 15 device desensitizing the LMS fixed site receiver.

Table 9 shows the calculated distances of an outdoor Part 15 radio to give 0, 10 and 20dB desensitization of the LMS fixed site. The distances are calculated for various transmitted power levels. Thus, the effect of directional antennas or reduced power can be seen.

Table 9 - Outdoor Pt 15 radio interference distances
Using Egli formula
(assuming 9dBi antenna at fixed site)

Threshold	-102	-102	-102	-102	-102 dBm
Pt (ERP)=	**30**	**20**	**10**	**0**	**-10 dBm**
hb=	200	200	200	200	200 ft
hm=	30	30	30	30	30 ft
R=	**11.48**	**6.46**	**3.63**	**2.04**	**1.15 mls**
Threshold	-92	-92	-92	-92	-92 dBm
Pt (ERP)=	**30**	**20**	**10**	**0**	**-10 dBm**
hb=	200	200	200	200	200 ft
hm=	30	30	30	30	30 ft
R=	**6.46**	**3.63**	**2.04**	**1.15**	**0.65 mls**
Threshold	-82	-82	-82	-82	-82 dBm
Pt (ERP)=	**30**	**20**	**10**	**0**	**-10 dBm**
hb=	200	200	200	200	200 ft
hm=	30	30	30	30	30 ft
R=	**3.63**	**2.04**	**1.15**	**0.65**	**0.36 mls**

Summary

Required distance of outdoor Part 15.247 from LMS fixed site for 0, 10 and 20 dB desensitization.			
Desensitization	0dB	10dB	20dB
No antenna directivity	11.5	6.5	3.6 miles
-20dB antenna directivity	3.6	2.0	1.2 miles

Any outdoor Part 15 device, within 3.6 miles of an LMS receiving site could desensitize that site by 20 dB. This is very significant interference and is potentially disasterous for the LMS system. The use of directional antennas by the outdoor device could improve the situation but, even if the signal was reduced by 20 dB in the direction of the LMS fixed site, over a mile separation is still required.

6.2. Near-Far Ratio for outdoor Part 15 blocking LMS fixed site

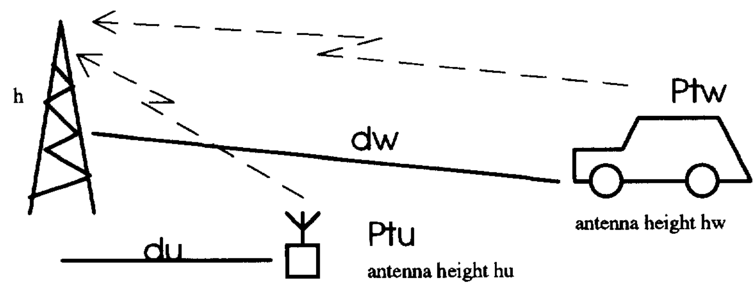

Figure 4 - Outdoor Part 15 interfering with WB fixed site reception

The calculation is similar to that in section 5.3. with the exception that there is no floor loss (f) and that the antenna height of the Part 15 radio is higher. The calculated near-far-ratios for blocking of the LMS fixed site reception of location burst are given in Table 10 and the blocking of the narrow band data/voice channels in Table 11.

Table 10 - Calculation of Near-Far ratio

Outdoor Part 15 blocking LMS fixed site reception

Location burst

Ptw, dBm	40	40	40	40	40
JM dB	15	15	15	15	15
Ptu, dBm	30	20	10	0	-10
hw, ft	6	6	6	6	6
hu, ft	30	30	30	30	30
dw/du	3.35	5.96	10.61	18.86	10.61
dw =	6	miles			
du =	1.79	1.01	0.57	0.32	0.57

Table 11 - Calculation of Near-Far ratio					
Outdoor Part 15 blocking LMS fixed site reception					
Narrow band channels					
Ptw, dBm	40	40	40	40	40
S/N,dB	10	10	10	10	10
Ptu, dBm	8	5	-2	-5	-12
hw, ft	6	6	6	6	6
hu, ft	30	30	30	30	30
dw/du	1.89	2.82	3.35	5.02	2.51
dw =	6	miles			
du =	3.18	2.13	1.79	1.20	2.39

Tables 10 and 11 confirm the desensitization problem. It can be seen that the LMS fixed site will experience severe interference problems with outdoor Part 15 radios. This is due to the height as well as the transmitted power of the Part 15 device. In general these outdoor devices are transmitting constantly and thus the interference is constant.

Table 10 shows that using directional antennas to reduce the effective radiation in the direction of the LMS fixed site, could reduce the interference, but the level of interference is still high. Unfortunately, from sales literature for several of these outdoor products, it is noted that high gain directional antennas are being sold as part of the installation, thus making the effective radiated power much higher than allowed. At present directional antennas are not being used to simply reduce the radiated angle.

Section 8 discusses these outdoor Part 15 issues in more depth.

6.3. Near-Far Ratio for outdoor Part 15 blocking LMS mobile

The LMS mobile receives both high power (300W ERP) narrow band data signals on its command channel and lower power (10W) data and voice signals. Obviously the lower power signals are the most at risk. Figure 5 shows diagrammatically the situation. Table 12 gives the calculated results.

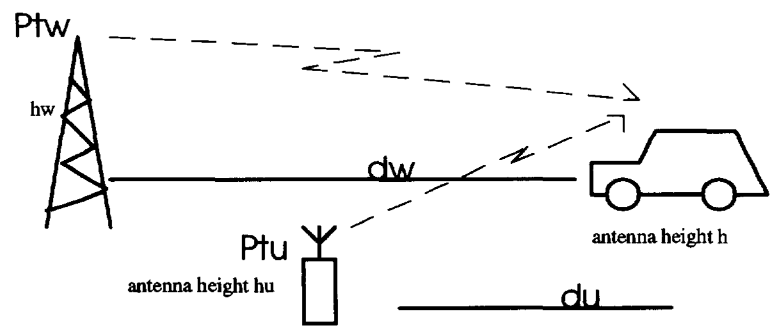

Figure 5 - Outdoor Part 15 interfering with WB mobile reception

Table 12 - Calculation of Near-Far ratio

Outdoor Part 15 blocking LMS mobile reception

Low level Narrow band channels

Ptw, dBm	40	40	40	**40**	40
S/N,dB	10	10	10	**10**	10
Ptu, dBm	30	14	11	**8**	5
hw, ft	200	200	200	**200**	200
hu, ft	30	30	30	**30**	30
dw/du	6.49	7.71	9.16	**10.89**	14.52
dw =	6	miles			
du =	0.93	0.78	0.65	**0.55**	0.41

The outdoor Part 15 radio is usually a wideband device of about 4 - 6 MHz. From Table 12 it can be seen that if a mobile is 6 miles from its fixed site and within about half a mile of the Part 15 device, the mobile is likely to be blocked. If the mobile is 3 miles from its fixed site (an average figure) then there could be a quarter mile 'black-out' area around the outdoor Part 15 site. Use of directional antennas will reduce the 'black out' area to a narrower beam, thus reducing the interference potential for an LMS mobile.

6.4. Near-Far Ratio for LMS mobile blocking outdoor Part 15

Figure 6 shows diagramatically the situation. Table 13 gives the calculated near-far-ratios.

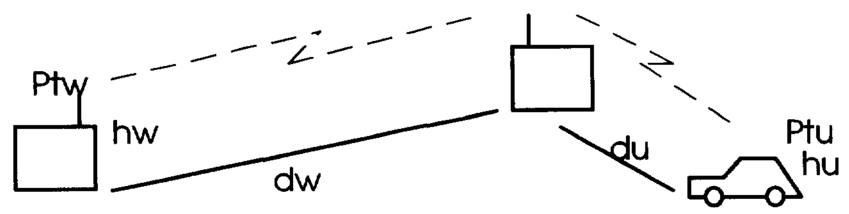

Figure 6 - LMS mobile blocking outdoor Part 15 reception

Table 13 - Calculation of Near-Far ratio

LMS mobile blocking outdoor Part 15 reception

Ptw, dBm	30	30	30	30	30
J/M	0	0	0	0	0
Ptu, dBm	40	30	20	10	0
hw, ft	30	30	30	30	30
hu, ft	6	6	6	6	6
dw/du	1.26	2.24	3.98	7.07	12.57
dw =	1	mile			
du =	0.80	0.45	0.25	0.14	0.08

dw =	3	mile			
du =	2.39	1.34	0.75	0.42	0.24

Table 13 shows that there is a real chance of interference from the LMS mobile. The inteference is higher the greater the Part 15 link distance e.g. for a link of 1mile, the mobile must be closer than 0.8 mile, but for a 3 mile link the mobile can be 2.4 miles away.

Table 13 also shows the effect of using directional antennas on the Part 15 link. Using a 20 dB antenna directivity will increase the NFR from 1.26 to almost 4.

An individual LMS mobile interference only transmits very infrequently and therefore in practice the experienced interference will be low.

6.5. Near-Far Ratio for LMS fixed site blocking outdoor Part 15

Tables 13 and 14 give the calculated results for the high power command channel and the low power data/voice channels, respectively.

Table 13 - Calculation of Near-Far ratio

LMS fixed site blocking outdoor Part 15 reception

Command channel

Ptw, dBm	30	30	30	30	30
J/M	0	0	0	0	0
Ptu, dBm	55	45	35	25	15
hw, ft	30	30	30	30	30
hu, ft	200	200	200	200	200
dw/du	0.09	0.16	0.29	0.52	0.92
dw =	1	mile			
du =	10.89	6.12	3.44	1.94	1.09

dw =	3	mile			
du =	32.66	18.37	10.33	5.81	3.27

Table 13 shows that the Part 15 radio will suffer extreme intereference from the command channel even if 20 dB of antenna directivity is used with the Part 15 device . Even with a 1 mile link distance and a 20 dB directional antenna protection, a fixed site within 3.44 miles of the Part 15 radio will block reception.

Table 14 - Calculation of Near-Far ratio					
LMS fixed site blocking outdoor Part 15 reception					
Data/voice channels					
Ptw, dBm	30	30	30	30	30
J/M	0	0	0	0	0
Ptu, dBm	40	30	20	10	0
hw, ft	30	30	30	30	30
hu, ft	200	200	200	200	200
dw/du	0.22	0.39	0.69	1.22	2.18
dw =	1	mile			
du =	4.59	2.58	1.45	0.82	0.46

Table 14 shows that the outdoor Part 15 link could experience significant interference from the lower power narrow band channels from the LMS fixed site.

6.6. Summary

There could be significant blocking of an LMS fixed site by an outdoor Part 15 radio if it is transmitting 1W in the LMS band. With 20 dB less power, the outdoor Part 15 radio needs to be over a mile away from the fixed site to avoid interference.

An LMS mobile within about a quarter mile of an outdoor Part 15 1W transmitter will be unable to receive narrow band data or voice.

There is a very good possibility of an LMS mobile interfering with the reception of an outdoor Part 15 radio, depending on the Part 15 link distance. For a link distance of 1 mile, a mobile within 0.8 miles has the potential to interfere.

An LMS transmitting site will severely interfere with the outdoor Part 15 link.

The outdoor Part 15 radios and the LMS system are liaible to interefere with each other, and therefore in those cases it is probable that the outdoor Part 15 devices will be set to the center of the band. This is further discussed in section 8.

Setting the power level compatible with the distance of the link and the use od directional antennas could alleviate some of the problem.

7. *Part 15 Mutual Interference*

7.1. Outdoor Part 15 interfering with another outdoor Part 15

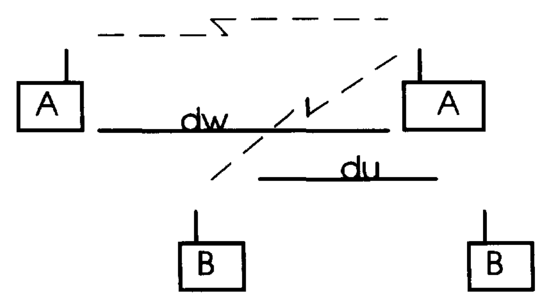

Figure 7 - One outdoor Part 15 radio link interfering with another

Table 15 - Calculation of Near-Far ratio
outdoor Part 15 link interfering with another

Ptw, dBm	**30**	30	30	**30**	30
J/M	**0**	0	0	**0**	0
Ptu, dBm	**30**	20	10	**0**	-10
hw, ft	**30**	30	30	**30**	30
hu, ft	**30**	30	30	**30**	30
dw/du	**1.00**	1.78	3.16	**5.62**	10.00
dw =	**1**	mile			
du =	**1.00**	0.56	0.32	**0.18**	0.10

dw =	**3**	mile			
du =	**3.00**	1.69	0.95	**0.53**	0.30

As Table 15 shows, the mutual interference is higher than that from an LMS mobile. Directional antennas may be used to reduce the interference.

7.2. Outdoor Part 15 interfering with indoor Part 15

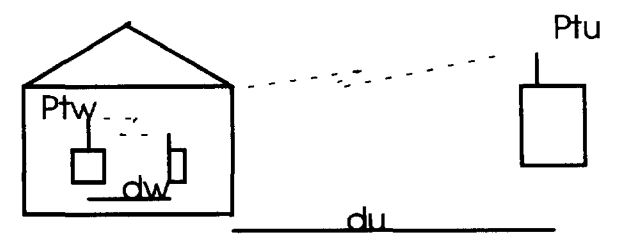

Figure 8 - Outdoor Part 15 interfering with indoor Part 15

Table 16 - Calculation of Near-Far ratio Outdoor Part 15 link interfering with indoor Part15				
Ptw, dBm	30	30	0	0
JM dB	0	0	0	0
Ptu, dBm	30	10	30	10
hw, ft	6	6	6	6
hu, ft	30	30	30	30
f, dB	10	10	10	10
dw/du	0.80	2.51	0.14	0.45
dw =	50	feet		
du =	62.87	19.88	353.55	111.80

In Table 16 the cases are shown for 1W (30dBm) and 1mW (0dBm) transmitted power for the indoor link. The effect of directional antenna on the outdoor link is shown as 30 dBm and 10 dBm transmitted power, Ptu. Table 16 shows that although the NFRs are poor, the short range of the indoor link means that the outdoor Part 15 radio needs to be very close in order to cause interference. The interference from an outdoor Part 15 is slightly worse than that from an LMS mobile with the added problem that the outdoor Part 15 will probably be constantly transmitting.

7.3. Indoor Part15 interfering with another indoor Part 15.

From the results in Table 16, it can also be concluded that because there would be an extra 10dB attenuation of the unwanted signal due to penetration loss, the interference between indoor Part 15 links is negligible.

7.4. Indoor Part 15 interfering with outdoor Part 15.

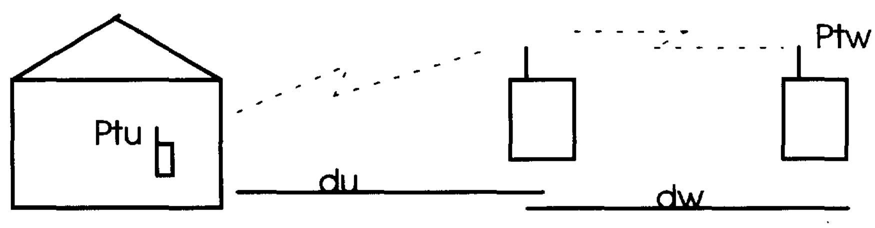

Figure 9 - Indoor Part 15 interfering with outdoor Part 15

Table 17 - Calculation of Near-Far ratio

Indoor Part 15 link interfering with outdoor Part15

Ptw, dBm	30	30	30	30	30
JM dB	0	0	0	0	0
Ptu, dBm	30	20	10	0	-10
hw, ft	30	30	30	30	30
hu, ft	6	6	6	6	6
f, dB	10	10	10	10	10
dw/du	3.98	7.07	12.57	22.36	39.76
dw =	1	mile			
du =	0.25	0.14	0.08	0.04	0.03

Table 17 shows that there is little chance of interference.

7.5. Summary

The interference from an outdoor Part 15 transmitter on another outdoor Part 15 receiver is slightly worse than the interference from an LMS mobile. With the use of directional antennas, it should be possible to overcome most problems.

Indoor Part 15.249 devices could experience interference from outdoor Part 15 devices, depending on the link distance. The interference potential is higher than that from the LMS mobiles and other indoor Part 15 radios.

Indoor Part 15.247 radios could interfere with outdoor Part 15 links if they are within a quarter mile of each other but in general there is little possibility.